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The Impact of Time Delays in Network Synchronization in a Noisy Environment[1]

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Coordinating, distributing, and balancing resources in networks is a complex task and it is very sensitive to time delays. To understand and manage the collective response in these coupled interacting systems, one must understand the interplay of stochastic effects, network connections, and time delays. In synchronization and coordination problems in coupled interacting systems individual units attempt to adjust their local state variables (e.g., pace, orientation, load) in a decentralized fashion. They interact or communicate only with their local neighbors in the network, often with explicit or implicit intention to improve global performance. Applications of the corresponding models range from physics, biology, computer science to control theory. I will discuss the effects of nonzero time delays in stochastic synchronization problems with linear couplings in an arbitrary network. Further, by constructing the scaling theory of the underlying fluctuations, we establish the absolute limit of synchronization efficiency in a noisy environment with uniform time delays, i.e., the minimum attainable value of the width of the synchronization landscape.[2] These results have also strong implications for optimization and trade-offs in network synchronization with delays.

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[2]D. Hunt, G. Korniss, and B.K. Szymanski, Phys. Rev. Lett. 105, 068701 (2010).